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EFFECTS OF WATER FLOW RESTRICTION AND ENVIRONMENTAL FACTORS ON PERFORMANCE OF NURSERY-AGE PIGS

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Summary

A series of three feeding trials was conducted to determine if nipple waterer flow rate affects the performance of nursery-age pigs and if there are any interaction effects with environmental factors. In the first trial, 42 barrows, 10 wk of age, were fed during a period of 4 wk at 5 or 35 C and given water ad libitum with flow rates of 100, 600 and 1,100 ml/min and a control treatment of 20 C and 600 ml/min. There was a linear increase in body weight gain from .278 kg/d at 100 ml/min to .466 kg/d at 1,100 ml/min when pigs were fed at 35 C. There was a linear decrease in weight gain from .855 kg/d at 100 ml/min to .730 kg/d at 1,100 ml/min when pigs were fed at 5 C. The weight gain of control treatment pigs (.775 kg/d) equalled that of the pigs fed at 5 C and 600 ml/min flow rate (.744 kg/d). In the second trial, 120 crossbred barrows and gilts were weaned at 4.5 wk and fed in a commercial-type nursery held at 30 C for 4 wk, with water provided at rates of 100, 350, 600, 850 and 1,100 ml/min. There was no measurable effect of water flow rate on body weight gain, feed intake or feed conversion. Water use increased as flow rate increased, and time spent drinking at 100 ml/min increased nearly fourfold above the average time spent drinking by the other treatments. In the third trial, 72 crossbred pigs weaned at 4.5 wk were assigned to six treatments to evaluate the effects of heating water to 30 C at an environmental temperature of 5 C and the effects of solid or wire mesh pen walls at 5 and 20 C using unheated water at a constant water flow rate of 600 ml/min. Open or solid pen walls had no effects on pig performance; however, at 5 C, heated drinking water increased body weight gain above unheated water and 5 C caused an increase in feed intake and feed required per unit gain above that at 20 C.

(Key Words: Nursery Pigs, Water Consumption, Water Restriction, Environmental Temperature, Growth, Nipple Waterers.)

Introduction

Nipple waterers are widely used to provide fresh drinking water to livestock. Water flow rates of such waterers vary considerably through variations in design and manufacture, and through partial plugging that reduces the rate at which water is delivered to the animals (Olsson, 1983). Design flow rates for nipple waterers are apparently based on subjective information, with one manufacturer using minimal water wastage by drinking animals as the desgin criterion. Partial plugging, which can go undetected because some water is available when the waterers are checked, can result in decreased water consumption, feed intake and weight gain of pigs as noted in a recent experiment (J. A. Nienaber, unpublished data).

Because nipple waterer flow rates for optimal production are unknown, a study was conducted to determine the influence of water flow rate on performance of nursery pigs housed at selected air temperatures. The effect of air temperature on water flow rate requirements and the effects of open or solid pen walls on pig performance were also evaluated.

Experimental Procedure

Trial I. Commercial nipple waterers were supplied with water by gravity from individual tanks for each pen of pigs. Manufacturer recommendations ranged from 400 to 800 ml/min depending on the animal weight. The restricted flow rate encountered in the earlier experiment was measured at 100 ml/min.

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Therefore, nominal water flow rates of 100, 600 and 1,100 ml/min were selected to cover a range of conditions beyond that recommended by the manufacturer. The 1,100 ml/min treatment was observed to be more than 10 wk old pigs could physically accommodate because of the splashing that occurred which resulted in obvious waste. Orifices were drilled in blank plates of the type normally used by the manufacturer to provide the desired flow rates. Because of the low delivery pressure, the highest flow rate also required some machining of the spindle of each waterer. Flow rates achieved were within 5% of the nominal values.

Because water requirements of pigs are dependent on environmental temperature, 5 and 35 C were selected to represent cold and hot conditions for comparison with a control treatment of 20 C and 600 ml/min flow rate.

A system was designed to measure frequency of drinking. Each water line was wrapped for a distance of 15 cm with heat tape operating at about 35 C. A thermocouple was inserted in the waterline to monitor water temperature downstream from the heat tape and temperatures were scanned every 10 s. When drinking occurred, water from the storage tank reduced the temperature of the water sensed by the thermocouple.

Forty-two barrows, approximately 10 wk old and averaging 23.3 kg, were assigned (three pigs/pen) to two replications of each of seven treatments (5 and 35 C with 100, 600 and 1,100 ml/min and 20 C with 600 ml/min). The animals were moved to the temperature-controlled rooms initially set at treatment temperatures but with all nipple waterers set at a flow rate of 600 ml/min. After 1 wk of adaptation to the facilities, treatment flow rates were imposed for a 4-wk period. Pigs were individually weighed three times/wk and ad libitum feed and water intakes were measured each week on a pen basis. Blood samples were taken by venipuncture (anterior vena cava) each week to check the hematocrit. Packed cell volume was determined by the microhematocrit method.

Pen means were analyzed with a two-way-analysis of variance model. Data from the 20 C, 600 ml/min treatment were included for comparisons only and were not used in the analysis.

Trial II. Results from Trial I indicated that flow rate significantly affected growth, especially at 35 C. Therefore, this trial was designed to establish a functional relationship between water flow rate and animal performance at an elevated air temperature. Treatment flow rates of 350 and 850 ml/min were added to the 100, 600 and 1,100 ml/min rates previously used. Two nipple waterers were provided in each pen of eight pigs. Water level in the supply tank for each pen was checked daily with fresh water added as needed. No measures of frequency of drinking were made. The 4-wk trial was conducted in a commercial raised-deck nursery with continuous recirculating air maintained at 30 C. A total of 120 crossbred barrows and gilts, averaging 6.7 kg, were weaned and moved to pens in the nursery at 4.5 wk of age. Pigs were ranked by weight, divided into three weight classes to minimize variation within each pen, then within weight classes (blocks) assigned randomly to pens. Pens were then assigned to treatments in a complete block design. The average initial weights of each treatment were nearly equal. Feed and water were provided ad libitum and feed, water and animal weights were recorded weekly.

A preliminary analysis of the data showed that the effects of initial weight and therefore blocks were linear. Therefore, the analysis reported here resulted from a one-way analysis of covariance model.

Trial III. Trials I and II had contrasting results indicating that some factor or factors were interacting with water flow rate to affect animal growth rate. Factors that differed between those trials included room temperature (30 vs 5 and 35 C), pen wall design (open wire mesh vs solid-wall enclosures) and slightly heated drinking water as a result of the system used to measure drinking frequency. Therefore, the third trial was designed to evaluate the effects on pig performance of environmental temperature (5 and 20 C), pen wall design (open mesh or solid) and heated water in a 5 C environment. A constant water flow rate of 600 ml/min was provided to each pen. A total of 72 pigs (barrows and gilts) averaging 7.4 kg, were assigned randomly, four pigs/pen to three replications of six treatments: 20 C and pens with solid or open mesh walls; 5 C and pens with solid walls and heated water or unheated water; 5 C and pens with open mesh walls and heated water or unheated water. All pens were identical in construction to those used in Trial I, except the sidewalls. Wire mesh (4-mm wire with 10 x 10 cm openings) similar to that used in the nursery of Trial II, was used to replace

TABLE 1. EFFECTS OF WATER FLOW RATE (ML/MIN) AND THERMAL ENVIRONMENT (C) ON PERFORMANCE OF PIGS (TRIAL I)[a], ON A PER PIG BASIS

Treatment: Temp., C	Treatment: Flow, ml/min	No. pens	Feed, kg/d	Water, liters/d	Weight gain, kg/d	Feed conversion, kg/kg	Frequency, drinks/h	Drink time[b], min/d	Hematocrit, %
Main effects									
5		6	2.15 ± .08	4.10 ± .29	.786 ± .023	2.74 ± .11	2.21 ± .13	14.7 ± 5.7	41.4 ± .3
35		6	.98 ± .08	7.33 ± 1.52	.376 ± .035	2.64 ± .11	3.17 ± .14	18.2 ± 4.3	34.9 ± .7
	100	4	1.49 ± .44	3.20 ± .11	.567 ± .167	2.64 ± .09	3.47 ± .13	32.0 ± 1.1	37.5 ± 2.3
	600	4	1.58 ± .27	6.22 ± 1.25	.579 ± .113	2.78 ± .11	2.59 ± .17	10.4 ± 2.1	39.0 ± 1.6
	1,100	4	1.64 ± .32	7.73 ± 1.85	.598 ± .076	2.66 ± .21	2.01 ± .14	7.0 ± 2.4	37.9 ± 2.0
Interaction effects									
5	100	2	2.24 ± .16	3.26 ± .14	.855 ± .009	2.62 ± .22	3.23 ± .15	32.6 ± 1.4	41.4 ± .4
5	600	2	2.04 ± .15	4.43 ± .41	.774 ± .006	2.64 ± .18	1.83 ± .06	7.4 ± .7	41.7 ± 1.0
5	1,100	2	2.18 ± .14	4.62 ± .04	.730 ± .002	2.99 ± .19	1.56 ± .08	4.2 ± .1	41.2 ± .6
20[c]	600	2	2.05 ± .17	5.14 ± .61	.775 ± .021	2.64 ± .15	2.21 ± .09	8.6 ± 1.0	39.7 ± .4
35	100	2	.74 ± .01	3.13 ± .21	.278 ± .011	2.66 ± .06	3.48 ± .15	31.3 ± 2.2	33.6 ± .5
35	600	2	1.12 ± .05	8.02 ± 1.67	.384 ± .013	2.92 ± .04	3.36 ± .16	13.4 ± 2.8	36.4 ± .5
35	1,100	2	1.09 ± .05	10.83 ± 1.10	.466 ± .013	2.34 ± .18	2.45 ± .20	9.9 ± 1.0	34.6 ± 1.5
Statistical significance									
Environmental temperature			P<.01	P<.01	P<.01	NS	P<.01	P<.05	P<.01
Water flow rate			NS[d]	P<.01	P<.05	NS	P<.01	P<.01	NS
Temp. X flow			NS	P<.01	P<.01	NS	P<.01	NS	NS

[a]Means ± SE. Pens used as experimental units, three pigs/pen.

[b]Derived measure: Water (liters/d) X ml/liter ÷ nominal waterer flow rate (ml/min) = drink time (min/d).

[c]20 C used for comparison only.

[d]NS indicates not significant (P>.10).

the solid metal side panels. A .3-m space was provided around each open mesh pen. Heated water was obtained by wrapping heat tape and insulation around appropriate supply tanks and water lines, and water temperature was maintained near 30 C. Animals were moved to temperature-controlled chambers and assigned to respective treatments upon weaning at approximately 4.5 wk of age. Treatment conditions were maintained for 6 wk following a 1-wk adaptation period. Individual animals were weighed three times/wk, with ad libitum feed and water consumption recorded weekly.

The data were analyzed as two-way-analysis of covariance models, with initial weight fitted as a linear covariate. The two analyses had the 5 C-unheated waterers with solid or open mesh wall treatments in common.

Results

Trial I. The effects of water flow rate and environmental temperature on pig performance are shown in table 1. Growth rate increased with increasing water flow rate at 35 C, but decreased with increasing flow rate at 5 C resulting in an interaction effect (P<.01) between flow rate and environmental temperature. There was also a decrease in growth rate (P<.01) at 35 C compared to 5 C and an improved average growth rate (P<.05) with increasing flow rate.

Feed intake decreased as temperature increased (P<.01) and there was a nonsignificant trend toward reduced feed intake with reduced flow rate at 35 C; however, there was no significant thermal effect or water flow rate effect on feed conversion.

Water consumption increased and drinking frequency decreased (P<.01) as temperature and flow rate increased. The highest flow rate (1,100 ml/min) was observed to be wasteful. Significant interactive effects (temperature × flow rate) were noted on drinking frequency (P<.01) and water consumption (P<.05).

Time spent drinking decreased as flow rate increased (P<.01) and temperature decreased (P<.05). Pigs on the low flow rate treatment spent approximately 30 min drinking each day at 5 and 35 C. Almost twice as much time was spent drinking at the medium and high flow rates for pigs maintained at 35 C compared with pigs at 5 C (table 1).

Temperature had an effect (P<.01) on hematocrit, but water flow rate within each

TABLE 2. EFFECTS OF WATER FLOW RATE (ML/MIN) ON PERFORMANCE OF PIGS IN A 30 C NURSERY (TRIAL II)[a], ON A PER PIG BASIS

Treatment, ml/min	Initial wt[b], kg	Feed, kg/d	Water[c], liters/d	Weight gain, kg/d	Feed conversion, kg/kg	Drink time[d], min/d
100	6.71 ± .94	.49 ± .03	1.57 ± .59	.288 ± .013	1.69 ± .07	16.5 ± .8
350	6.57 ± .94	.49 ± .03	2.25 ± .59	.289 ± .013	1.68 ± .07	5.6 ± .8
600	6.50 ± .94	.47 ± .03	2.93 ± .59	.291 ± .013	1.62 ± .07	3.6 ± .8
850	6.85 ± .94	.51 ± .03	3.72 ± .59	.279 ± .013	1.82 ± .07	4.2 ± .8
1,100	6.71 ± .94	.52 ± .03	5.20 ± .59	.289 ± .013	1.81 ± .07	3.4 ± .8

[a]Means ± SE from three pens of eight pigs each. Pens used as experimental units.

[b]Initial weight averaged 6.67 kg and was a significant linear covariate for feed intake and body weight gain (P<.01).

[c]Flow rate increased water use (P<.05).

[d]Flow rate reduced drinking time (P<.01) calculated on the same basis as in table 1.

temperature treatment (5 and 35 C) had no effect (table 1).

Trail II. Results from Trial II showed no effects (P>.10) of waterer flow rate on weight gain, feed intake or feed conversion of animals even though water consumption decreased (P<.05) with water flow rate. Performance results for the 4-wk trial are shown in table 2. Drinking time was similar (3.4 to 4.2 min/pig daily) over the range of 600 to 1,100 ml/min. Pigs in the 350-ml/min treatment spent 5.6 min/pig daily drinking while pigs on the 100 ml/min treatment had a fourfold increase in time spent drinking. Feed intake and weight gain were positively correlated (P<.01) to initial weight.

Trial III. Heated water and pen wall construction treatment effects on performance at 5 C are shown in table 3. Heated water (30 C) increased weight gain (P<.05) at 5 C, with a resultant improved (P<.09) feed conversion. Pen walls had no effect on growth or feed and water intakes. Initial weight was linearly correlated to feed intake (P<.01) and weight gain (P<.01), as well as water use (P<.05).

Room air temperature and pen wall construction treatment effects on performance are shown in table 4. Feed intake was lower (P<.01) and feed conversion was improved (P<.01) at 20 C compared with 5 C; however, there was no measurable effect on weight gain. There was also no effect of pen wall or interaction of pen wall and temperature. Initial weight was positively correlated to weight gain (P<.01).

Discussion

Water consumption volumes measured in Trials I and II were similar to the results of Mount et al. (1971), who reported that there was little difference in water consumption from 7 to 22 C, but water intake increased at 30 and 33 C. Mount et al. (1971) reported that pigs averaging 21 kg drank 2.5, 2.6 and 3.9 liters/d at air temperatures of 10, 20 and 30 C, respectively, when given water ad libitum and fed 42 to 52 g feed/kg body weight; the ratio of water to feed consumption ranged from 2.6 to 4.2 liters/kg at temperatures of 10 to 30 C. A subsequent study (Nienaber, 1981), with pigs averaging 21 kg, measured average water consumptions of 1.5, 1.8 and 3.5 liters/d and water:feed consumption ratios of 1.4, 1.7 and 5.0 at air temperatures of 5, 20 and 35 C, respectively. Barber et al. (1963) reported no

TABLE 3. PERFORMANCE MEANS AND STANDARD ERRORS OF PIGS AS AFFECTED BY WATER TEMPERATURE AND PEN WALLS AT 5 C (TRIAL III)[a], ON A PER PIG BASIS

Treatment						
Water temp.	Pen wall	Initial wt[b], kg	Feed, kg/d	Water, liters/d	Weight gain, kg/d	Feed conversion, kg/kg
			Main effects			
Heated		7.45	1.58 ± .04	3.68 ± .15	.661 ± .013	2.39 ± .06
Unheated		7.01	1.57 ± .04	3.76 ± .15	.615 ± .013	2.56 ± .06
	Open	7.21	1.61 ± .04	3.84 ± .15	.645 ± .013	2.50 ± .06
	Solid	7.25	1.55 ± .04	3.60 ± .15	.632 ± .013	2.45 ± .06
			Statistical significance			
Water temperature			NS[c]	NS	P<.05	P<.09
Pen walls			NS	NS	NS	NS

[a]Means represent six observations.

[b]Initial weight linear covariate was significant for feed intake and weight gain (P<.01) and water use (P<.05). Values corrected to 7.23 kg.

[c]NS = P>.10.

TABLE 4. PERFORMANCE MEANS AND STANDARD ERRORS OF PIGS AS AFFECTED BY ROOM TEMPERATURE (C) AND PEN WALLS (TRIAL III)[a], ON A PER PIG BASIS

Treatment						
Water temp.	Pen wall	Initial wt[b], kg	Feed, kg/d	Water, liters/d	Weight gain, kg/d	Feed conversion, kg/kg
		Main effects				
5 C		7.45	1.59 ± .03	3.78 ± .23	.621 ± .018	2.56 ± .07
20C		7.65	1.37 ± .03	3.91 ± .23	.654 ± .018	2.11 ± .07
	Open	7.22	1.47 ± .03	3.98 ± .23	.637 ± .018	2.33 ± .07
	Solid	7.43	1.49 ± .03	3.72 ± .23	.638 ± .018	2.34 ± .07
			Statistical significance			
Water temperature			P<.01	NS	NS	P<.01
Pen walls			NS[c]	NS	NS	NS

[a]Means represent six observations.

[b]Initial weight linear covariate was significant for weight gain (P<.01). Values were corrected to 7.33 kg.

[c]NS = P>.10.

significant effect of the amount of water given on growth rate or feed conversion of 10-wk-old pigs when water was mixed with feed in ratios of 1.5, 2 and 3 liters/kg. However, when water was provided ad libitum in addition to 1.5 liters/kg given with feed, growth rate increased as a result of an increase in feed intake. Water intake increased to an average of 2.4 liters/kg, while feed conversion remained unaffected. There was no record of environmental temperatures, but there was no difference in water consumption or water to feed ratio between the winter and summer trials. The authors concluded that availability of water was the primary reason for the increased feed intake and growth rate because when given at a specific ratio, water was available only two times each day. Holme and Robinson (1965) found no difference in performance of pigs from 9 to 90 kg when given water in fixed ratios of 1.5 and 2.5 liters/kg or on an ad libitum basis. There were no environmental temperatures reported but animals were housed in a temperate climate, so that no temperature extremes were expected. These reports indicate the wide range of water supply situations to which the pig is adaptable, but also that there are limits to adaptation.

Adaptation was evident in the results from the second trial when growth of newly weaned pigs was unaffected by water flow rate. The primary adaptation made was in time spent drinking and drinking frequency. Because there was little difference in apparent time spent drinking (3.5 to 5.6 min/pig daily) across a wide range of flow rates (350 to 1,100 ml/min), it appears that the act of drinking is important and is probably controlled by some other acitvity causing thirst (eating or other bodily functions).

Adaptation was also apparent in differences of time spent drinking measured in Trial I. The apparent increase in water requirements at 35 vs 5 C was evident by pigs spending nearly twice as much time drinking at 35 C (medium and high flow rates). However, an apparent adaptation limit was reached with the low flow rate treatment because pigs spent approximately 30 min/d drinking at both 5 and 35 C. While this did not limit growth rate at 5 C, the low flow rate at 35 C caused a reduction in growth rate. Other indications of the limits of adaptation are the 2-kg growth deficit resulting from the unheated water at 5 C in Trial III and the 1.7-kg growth deficit at 5 C compared with 20 C. However, these deficits might well be negated before reaching slaughter weight through compensatory growth (Hahn, 1982).

Because water use increased with flow rate while time spent drinking remained constant in Trial II, water waste, rather than consumption, likely increased with flow rate. This observation is supported by the report of Olsson (1983) that lower water use was related to less water wasted, not less water consumed. He found that water use decreased as flow rate decreased; however, feed intake and growth rate remained unaffected. Carlson and Peo (1982) found that growth rate and feed conversion of newly weaned pigs improved with increased water flow rate in one experiment, but that a low flow rate was adequate in a second experiment. Although no direct comparisons could be made between their flow rates and those used in our study, it was estimated from their given pressure and orifice sizes that the low flow rate used by Carlson and Peo (1982) was greater than the maximum rate used here. Their reported water consumption was also greater than values found in our studies and averaged 3.4 and 5.8 liters/d for nipple waterers oriented 45° down and up, respectively. The authors noted that orientation had little effect on performance, and that the increased water use resulted from "pigs playing" with waterers more when oriented upward.

The high flow rate treatment in Trial I provided some evaporative cooling through water wastage to stimulate rate of weight gain at 35 C, but reduced it at 5 C. Because it was not known whether rate of gain at 5 C was stimulated by the lowest flow rate or by the heated water, the third trial was designed to evaluate the possible benefit of heating water in a cold environment. The significant increase in weight gain and improved feed conversion with heated water is perhaps related to the findings of Holmes (1970, 1971) that pigs fed cooled whey (15 C) grew slower and were less efficient than pigs given heated whey (40 C). It was found that the temperature of the ingested whey significantly affected the core temperature of the pigs housed at 16 or 22 C. It was estimated that the "heat of warming" the cool whey may have accounted for the entire effect on rate of gain. However, the author concluded that, at that time, space heating would be a more practical means of increasing performance than heating the whey. The heating of whey and heating water may not be practical today but these results provide an alternative means of offsetting low temperatures and might be considered in the future.

These trials have demonstrated that the pig is adaptable to restrictions of its water supply but that there are limits of adaptation. The restricted flow rate in the first trial exceeded the limits of adaptation at 35 C but not at 5 C. The younger pigs used in the second trial conducted at 30 C demonstrated that, by increasing time spent drinking, sufficient water was consumed to maintain normal growth rate. Therefore, as pigs get heavier and temperatures rise, attention to water flow rate becomes more important.

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